MULTIMEDIA UNIVERSITY®

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2022/2023 (TERM ID 2215)

ERF2046 ELECTROMAGNETICS WITH APPLICATIONS

(All Sections / Groups)

15 FEBRUARY 2023
2:30 P.M. – 4:30 P.M.
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This question paper consists of 7 pages including this cover page with 4 questions only. Common constants for air are listed on Page 5. Equations are listed on Page 5, 6 and 7.

2. Attempt all four questions. All questions carry equal marks and the distribution of marks for each question is given.

3. Please print all your answers in the answer booklet provided.

Question 1 (25 marks)

(a) State coulomb's law and write down its mathematical expression.

[6 marks]

(b) Point charges 7 nC and −3 nC are located at (2, 0, 4) and (−6, 1, 5), respectively.

(i) Determine the force on a 1nC point charge located at (1, −3, 5).

[9 marks]

(ii) Find the electric field **E** at (1, −3 , 5).

[2 marks]

(c) Figure Q1(c) depicts a capacitor consisting of two parallel conducting plates separated by a distance of 0.02 m. The space between the plates contains two adjacent dielectrics, one with permittivity $\varepsilon_r = 9$ and another with $\varepsilon_r = 5$. All dimensions are in meter. Determine:

(i) The capacitance, C for the configuration in Figure Q1(c).

[6 marks]

(ii) The energy stored in the capacitor, W if a voltage of 12 V is applied between the two conducting plates.

[2 marks]

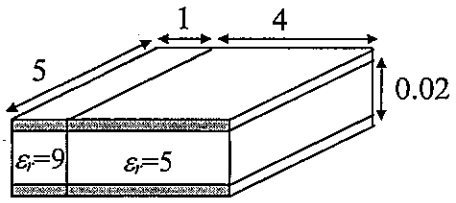

Figure Q1(c)

Continued ...

Question 2 (25 marks)

(a) A toroid with $N = 1800$ turns is lying on the x-y plane. It has an air core with cross sectional area $A = 25$ mm^2 and a mean radius $r = 30$ mm. Determine the inductance of the toroid.

[3 marks]

(b) The magnetic circuit shown in Figure Q2(b) is made of two different materials.

- The relative permeability of material 1 and material 2 are 850 and 500, respectively.
- Material 1 has a length, L_1 of 20 cm while material 2 has a length, L_2 of 8 cm.
- The cross sectional area for both materials are the same, $A_1 = A_2 = 3$ cm^2.

An air gap of 1 mm is created at material 2. A coil of $N = 1000$ turns is wound at material 1 and carries a current, $I = 0.5$ A. Assume that fringing effect is negligible,

(i) Construct the equivalent circuit for the magnetic circuit of Figure Q2(b).

[3 marks]

(ii) Calculate the total reluctance of the circuit.

[10 marks]

(iii) Determine the magnetic flux of the circuit.

[4 marks]

(iv) If a flux density of 0.5 T is required at the air gap, what should be the supplied current?

[5 marks]

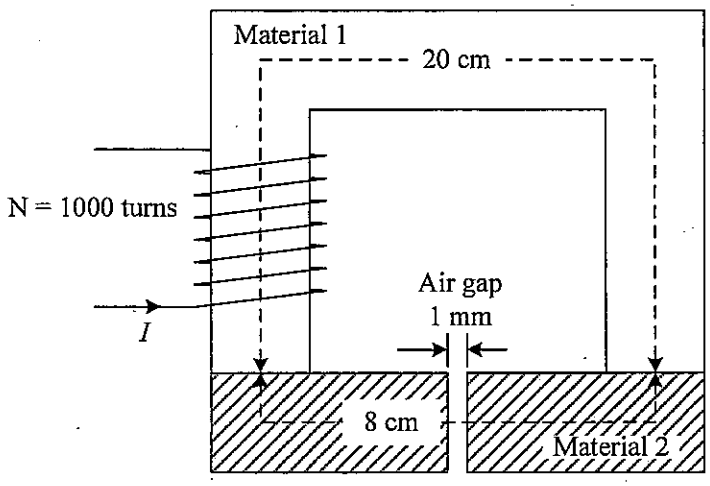

Figure Q2(b)

Continued ...

Question 3 (25 marks)

(a) The electric field component of a plane wave in a lossless dielectric is given by $\mathbf{E} = \hat{\boldsymbol{z}}\ 5\cos(2\pi \times 10^8 t - \beta x)$ V/m where $\beta = 5$ rad/m.
Given that the relative permeability, $\mu_r = 1$, determine:

(i) The frequency, f.

[1 mark]

(ii) The direction of propogation.

[1 mark]

(iii) The phase velocity, u_p.

[2 marks]

(iv) The wavelength, λ.

[2 marks]

(v) The dielectric constant, ϵ_r.

[3 marks]

(vi) The wave impedance, η.

[3 marks]

(vii) The polarization of the wave.

[2 marks]

(b) A coaxial cable of with a characteristic impedance of 50 Ω is connected to a load of 150 Ω. Determine the following transmission line parameters:

(i) Reflection coefficient at the load.

[3 marks]

(ii) Standing wave ratio.

[3 marks]

(iii) Input impedance at 0.1 λ from the load.

[5 marks]

Question 4 (25 marks)

(a) Sketch the radiation pattern of an isotropic antenna and a short dipole in two-dimensional and three-dimensional coordinate system.

[8 marks]

(b) A dipole antenna with a length of 1 cm is excited with a current of 200 mA at a frequency of 3 GHz. Determine the magnitude of the electric field along the antenna bore sight at a distance of 200 λ.

[9 marks]

(c) The transmitting and receiving antennas are separated by a distance of 500 λ and have gains of 25 and 28 dB, respectively. If 2 mW of power is to be received, determine the minimum transmit power.

[8 marks]

Continued ...

Common constants for air

Speed of light, c	$= 3 \times 10^8$ m/s
Permittivity, ε_0	$= 8.854 \times 10^{-12}$ F/m
Permeability, μ_0	$= 4\pi \times 10^{-7}$ H/m
Intrinsic impedance, η_0	$= 377\ \Omega$

Equations

Electrostatic

$\mathbf{F} = q\mathbf{E}$

$C = \dfrac{\varepsilon_0 A}{d}$ (Parallel plate)

$C = \dfrac{4\pi\varepsilon}{\dfrac{1}{a} - \dfrac{1}{b}}$ (Spherical)

$C = \dfrac{2\pi\varepsilon L}{\ln\dfrac{b}{a}}$ (Cylindrical)

$W = \dfrac{1}{2}CV^2$

$R = \dfrac{l}{\sigma A}$

Magnetostatic

$\mathbf{F} = q(\mathbf{u} \times \mathbf{B})$

$L = \dfrac{\mu N^2 A}{2\pi r}$ (Toroid)

$L = \dfrac{\mu l}{2\pi} ln\left(\dfrac{b}{a}\right)$ (Coaxial)

$\Re = \dfrac{l}{\mu A}$

Transmission Line

$u_p = \dfrac{\omega}{\beta} = f\lambda = \dfrac{1}{\sqrt{\mu\varepsilon}}$ $\qquad$ $\beta = \dfrac{2\pi}{\lambda}$

$\gamma = \alpha + j\beta = \sqrt{(R' + j\omega L')(G' + j\omega C')}$ $\qquad$ $Z_0 = \sqrt{\dfrac{R' + j\omega L'}{G' + j\omega C'}}$

Continued ...

Lossless:

$\gamma = j\omega\sqrt{L'C'}$, $Z_0 = \sqrt{\frac{L'}{C'}}$

$Z_{in}(l) = Z_0 \frac{Z_L + jZ_0 \tan\beta l}{Z_0 + jZ_L \tan\beta l}$

$Z_{in}^{oc}(l) = -jZ_0 \cot\beta l$

$Z_{in}\left(\frac{\lambda}{4}\right) = \frac{Z_0^2}{Z_L}$

$\Gamma_L = \frac{Z_L - Z_0}{Z_L + Z_0}$

Distortionless:

$\gamma = \sqrt{R'G'} + j\omega\sqrt{L'C'}$, $Z_0 = \sqrt{\frac{L'}{C'}}$

$Z_{in}^{sc}(l) = jZ_0 \tan\beta l$

$Z_0 = \sqrt{Z_{in}^{sc} Z_{in}^{oc}}$

$\tan(\beta l) = \sqrt{-\frac{Z_{in}^{sc}}{Z_{in}^{oc}}}$

$SWR = \frac{1 + |\Gamma|}{1 - |\Gamma|}$

Uniform Plane Wave

$u_p = \frac{\omega}{k} = \frac{1}{\sqrt{\mu\varepsilon}}$

$\lambda = \frac{2\pi}{k} = \frac{u_p}{f}$

$\tilde{\mathbf{H}} = \left(\frac{1}{\eta}\right)\hat{\mathbf{k}} \times \tilde{\mathbf{E}}$

$\tilde{\mathbf{E}} = -\eta\hat{\mathbf{k}} \times \tilde{\mathbf{H}}$

$\eta = \sqrt{\frac{\mu}{\varepsilon}}$

$\boldsymbol{S}_{ave} = \frac{1}{2\eta}|\tilde{E}|^2\hat{k}$

Lossy medium:

$\varepsilon_c = \varepsilon - j\frac{\sigma}{\omega} = \varepsilon' - j\varepsilon''$

$\eta_c = \sqrt{\frac{\mu}{\varepsilon'}}\left(1 - \frac{\varepsilon''}{\varepsilon'}\right)^{-\frac{1}{2}}$

$\gamma = \alpha + j\beta \qquad u_p = \frac{\omega}{\beta}$

$\delta_s = \frac{1}{\alpha}$

Low-loss dielectric:

$\alpha \cong \frac{\sigma}{2}\sqrt{\frac{\mu}{\varepsilon}} \quad \beta \cong \omega\sqrt{\mu\varepsilon} \quad \eta_c \cong \sqrt{\frac{\mu}{\varepsilon}}$

Good conductor:

$\alpha \cong \sqrt{\pi f \mu\sigma} \quad \beta \cong \alpha \quad \eta_c \cong (1+j)\frac{\alpha}{\sigma}$

Continued ...

Normal Incidence

$\Gamma = \frac{\eta_2 - \eta_1}{\eta_2 + \eta_1} \quad \tau = \frac{2\eta_2}{\eta_2 + \eta_1} \quad \tau = 1 + \Gamma$

Waveguide

$$f_{c_{mn}} = \frac{u_{p_0}}{2}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2} \qquad \beta_{mn} = \beta_0\sqrt{1 - \left(\frac{fc_{mn}}{f}\right)^2}$$

$$u_p = \frac{u_{p0}}{\sqrt{1 - \left(\frac{fc_{mn}}{f}\right)^2}} \qquad u_g = u_{p0}\sqrt{1 - \left(\frac{fc_{mn}}{f}\right)^2}$$

$$Z_{TM} = \eta\sqrt{1 - \left(\frac{fc_{mn}}{f}\right)^2} \qquad Z_{TE} = \frac{\eta}{\sqrt{1 - \left(\frac{fc_{mn}}{f}\right)^2}}$$

Antennas

Short Dipole:

$$E_\theta = \frac{j\omega\mu I_m L \sin\theta}{4\pi r} e^{-j\beta r}$$

$$H_\phi = \frac{j\beta I_m L \sin\theta}{4\pi r} e^{-j\beta r}$$

$$D = 1.5$$

$$R_{rad} = 80\pi^2\left(\frac{l}{\lambda}\right)^2$$

Friss Transmission Formula:

$$\frac{P_r}{P_t} = G_t G_r\left(\frac{\lambda}{4\pi r}\right)^2$$

End of paper